Track Elevation

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Track Elevation

TRACK ELEVATION.

A THESIS

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AND

[illegible]

TO THE

PRESIDENT OF THE FACULTY

OF ARMOUR INSTITUTE OF TECHNOLOGY

FOR THE DEGREE OF

BACHELOR OF SCIENCE IN CIVIL ENGINEERING

Having Completed The Prescribed Course Of Study In

CIVIL ENGINEERING

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TRACK ELEVATION.

The subject of track elevation is a very important one in view of the fact that nearly all railroads coming into the city of Chicago, and in fact all large cities, are elevating their tracks.

A few years ago none of the roads had their tracks elevated, which necessitated many grade crossings in the city and made it necessary to run trains at a comparatively low rate of speed, as well as making many dangerous crossings where accidents were quite frequent. By elevating the tracks all grade crossings were done away with, thus reducing the danger to human life and also allowing an increase in speed of trains.

In the last ten years nearly all roads leading into the city have elevated their tracks and it is the purpose of this thesis, to take up the computations and make all drawings necessary for the determination of all cost data as well as the final cost of the work.

The work taken up refers to that part of the Chicago, Rock Island & Pacific Railroad's tracks from 72nd. Street to and including 83rd.Street, a distance of 8600 feet. As the tracks are already elevated south to 76th. Street very little work is required up to that point. At 76th. Street the present tracks run down to grade. It is the intention to start the fill at the center line of 72nd. Street,and going south, have an ascending grade of .4% from that point to a point between 78th. and 79th. Streets where a maximum elevation of 30 feet is reached, this elevation being

necessary to enable the Chicago, Rock Island & Pacific Railroad tracks to pass over the tracks of the Chicago & Western Indiana Railroad tracks, which at the present time cross at grade.

From this point the grade is descending until the present grade of the track is reached, with the same rate of grade as the ascending grade, or .4%.

The surveying that was done in this work consisted of taking a profile of the present track and plotting that and the proposed profile as shown on Plate I. Cross-sections of the present road bed were taken and plotted, together with the proposed cross-sections. These cross-sections were taken at intervals of 100 feet and are shown drawn to scale on Plate II.

The angles between the intersection of the streets and also the angle of intersection of the Chicago & Western Indiana Railroad with the Chicago, Rock Island & Pacific Railroad. From this data the plan of the entire work was drawn (Plate III) and also the large scale plan of that part of the work extending from 78th. Street to and including 79th. Street. (Plate IV.)

The filling required begins at 72nd. Street and extends to 83rd. Street. The amount of fill was determined from the cross-sections (Plate II). The differences in areas of the present and proposed cross-sections were determined by means of a planimeter and the volume of fill required was calculated by the formula using average end areas into the length, the length in every case being 100 feet or less. Deduction was made for all street crossings.

The bridge work necessary is the raising of the present bridges located at 73rd., 74th., 75th., and 76th, Streets to the required elevation, and putting new Plate Girder bridges in at 79th., 80th., 81st., and 83rd. Streets. Through girders are to be used at the Streets named. Plates V, VI, VII, VIII, IX, X, XI, XII, show these bridges as they will be when the work is completed.

As shown in the plan (Plates IV, XIII, & IX), a system of deck plate girders is to be used from the crossing over the Chicago & Western Indiana Railroad to 79th. Street. Where necessary built-up steel posts will be used to support the girders thus making the length of all the deck girders approximately the same.

At the crossing of the Chicago & Western Indiana Railroad, through plate girders will be used, There will be steel posts, set between the tracks of the Chicago & Western Indiana Railroad's tracks, to shorten the spans of the girders. The reason for putting in these posts and for using through girders is to provide sufficient head room for the Chicago & Western Indiana Railroad in case they elevate their tracks, which it is proposed to do.

Where new through plate girders are put in the floor system shown in Plate XVIII.will be used. With this I-beam type of floor system the noise of passing trains is very slight, and the cost of building them is much less than for the old type of floor beams and stringers.

Owing to the large amount of filling required and to the narrow right of way, retaining walls must be built nearly the entire distance. Walls 5 feet high are to be built

from 75th. Street to 76th. Street and from 81st. Street to 82rd. Street. Walls 10 feet high are to be built from 80th. Street to 81st. Street and 12 foot walls from 76th. Street to the crossing over the Chicago & Western Indiana Railroad, and from 79th. Street to 80th. Street.

All retaining walls are to be built of cross-sections as shown in Plates XIV, XV, & XVI, and a mixture of 1 2 6 concrete is to be used in all of this work.

Abutments for the bridges will have to be built at 79th., 80th., 81st., and 82rd. Streets and for the plate girder system just north of 79th. Street.

The abutments under the bridges that are already in place at 73rd., 74th., 75th., and 76th. Streets will be used. At 73rd. Street new pedestals will be put in which will be of sufficient height to raise the girder to the required elevation. At 74th., & 75th. Streets the bridges will be raised and new parts built up under the girders on top of the old abutments. Timber cribs are to be built up under each set of 4 girders at points A, B, & C (Plate XVII), care being taken to jack up the middle first and let it take at all times fully half of the weight of the bridge. This is necessary on account of the side-walk not having as firm a foundation as the street.

Coffer dams of 12" X 2" or 10" X 2 "lagging with 6" X6" vertical posts are to be built at "X". By bracing the upright posts against the girders the posts can thus be made to stand when driven only about 5 feet in the present road-bed.

For the bridges at 73rd. and 74th. Streets the vertical posts need not.be set so deeply. As the girders are jacked

up the rails may be run across the small span between the end of the bridge and the coffer dams, and trains accommodated on all of the tracks.

The coffer dams at "X" are to be made vertical and the face will then serve as the back side of the forms for the added portion of the abutment.

On all of the bridges from 73rd. Street to 76th. Street the tracks are to be removed from their present rigid fastening to the bridge and ballast and wood ties put in to. carry the rails. There will be no bond (except ballast) between, either the ties or the rails, and the bridge floor.

At 76th. Street the new portion of the abutment will not only extend above the old abutment but will also extend down behind the old abutment to the original ground level thus insuring enough condrete to resist the overturning moment of the fill. This overturning moment will also be resisted to some extent by the bracing the girder tends to give to the abutment.

There being no rigid fastening between the rails and the bridge the roadbed will be more uniform and elastic and the noise of passing trains will be reduced to a minimum. With the increased head room given by the raising of the bridges, the grades of the streets may be restored to the original or natural elevation.

COST DATA.

The cost of the fill was determined by figuring the cost of the sand loaded on the cars, the cost of hauling the sand twenty-six miles, and the cost of unloading and placing.

The total volume of the sand required for the fill was determined, as previously stated, by finding the areas of the cross-sections of the fill required and multiplying the mean area by the length. In all cases the length was taken as 100 feet or less. By this method of calculations the total fill required was found to be 339,030 cubic yards. The cost of the sand, loaded on the cars at the pit, is 10¢, the cost of hauling 26 miles is 25¢ and the cost of unloading and placing is 5¢ making the total cost per cubic yard 40¢. The total cost of fill is then found to be, $.40 X 339,030 = $135,612.00

The fill thus determined did not include the ballast that is required. The amount of ballast required for the three tracks for 8600 feet or 1.62 miles is 22,934 cubic yards. Stone ballast will be used throughout the work, the cost of such ballast being $1.25 per cubic yard put in place under the track. The cost of the ballast is therefore;
$1.25 X 22,934 = $28,667.50

The next item in the track work is the ties. Ties are spaced 16 every 33 feet, thus making the number required 12,528. Ties that have been treated cost $.75 apiece on the ground under the rails. This makes the cost of ties
$.75 X 12,528 = $9,396.00

Rails F. O. B. cost $30.00 per gross ton. Using 90# rails 30 feet long the number required for the three tracks

is therefore 692. The cost is therefore $20.00 X 692 = $20,760

For rails 30 feet long 352 pairs of splice bars are required per mile of track. There being three tracks each 1.63 miles long the number of pairs of splice bars required is 3 X 1.63 X 352 = 1722

Using 6 hole splice bars weighing 70# per pair the total weight of splice bars required is 70 X 1722 = 120,540#. At 1.35¢ per pound the cost of splice bars is;
$.0135 X 120,540 = $1,627.29

Using spikes measuring 5 1/2" X 9/16" under head the number of kegs per mile is 28.16 Each keg contains about 375 spikes. The weight of each keg being 200# the weight of the spikes required for one mile is 5632#. The total weight of spikes for 4.89 miles is therefore 4.89 X 5632 = 27,540.48# At a cost of $.0175 per pound the total cost of spikes will be $.0175 X 27,540.48 = $481.96

Using a 30' rail with a 6 hole splice bar the number of bolts required for one mile of track is 2112. The total number of bolts required is therefore 4.89 X 2112 = 10,328. There being 170 bolts (4" X 7/8") in a keg of 200# the total weight of bolts is 10,328/170 X 200 = 12,150.6#. At a cost of $.024 per pound the total cost of track bolts is $291.62

In figuring the weights of girders in order to determine the cost, the table (Plate 19) was used. By this table, the length of span in all cases being known, the weight was found directly. There being four girders at each street crossing the total number of girders required for the crossings at 79th., 80th., 81st., & 83rd. streets is 16. The span of the girders in every case was 71 feet. From the table we find

that the total weight of a girder of 71 foot span is 59,000#. The total weight of these 16 girders is therefore 16 X 59,000= 944,000#. In the table given below the weights of the girders in the plate girder system just north of 79th. Street,are given;

Span.	No. of girders.	Weight of single girder.	Total weight.
69.6'	4	56,000#	224,000#
63'	1	46,000#	46,000#
54'	1	33,500#	33,500#
50'	1	29,000#	29,000#
40'	3	20,500#	61,500#
61'	8	43,000#	344,000#
57'	8	37,000#	296,000#
		Total weight	1,034,000#

Adding to this number the weight of the girders previously determined gives a total weight for all bridge work that is required of 1,978,000#. The bridge work in place costs 3 1/2¢ per pound thus making the total cost of bridge work;
$.035 X 1,978,000 = $69,230.00

Using 1 to 3 to 6 concrete in all retaining walls makes the cost per cubic yard $4.00 . The cross-sectional area of the five foot retaining walls is 15.5 square feet. The total length of this wall required is 3,287 feet, making the volume 15.5 X 3,287 = 62,262.5 cubic feet.

The volume of the ten foot and twelve foot retaining walls was determined in the same manner and the combined volume of the two is 440,236 cubic feet. The total volume of the concrete to be used in the retaining walls is therefore 502,499.5 cubic feet or 18,611.1 cubic yards. At the cost of

$4.00 per cubic yard as previously stated, the total cost of the retaining walls is $4.00 X 18,611.1 = $74,444.40 .

The same mixture of concrete being used in the abutements the cost per cubic yard will be the same. The volume of concrete required for the abutements is 12,530 cubic yards making the cost of abutements $4.00 X 12,530 = $50,120.00 . The total cost of the concrete work will therefore be the sum of the costs of the retaining walls and the abutements or $74,444.40 + $50,120.00 = $124,564.40 .

The total cost of the elevating of the distance of 8,600 feet is therefore;

Cost of fill	$135,612.00
" " Ballast	$ 28,667.50
" " Ties	$ 9,396.00
" " Rails	$ 20,760.00
" " Splice bars	$ 1,627.29
" " Spikes	$ 481.96
" " Track Bolts	$ 291.63
" " Bridge Work	$ 69,230.00
" " Concrete Work	$124,564.40
Total Cost	$390,830.77

As the work is to be done by contractors 20% must be added to the actual cost to allow for contractor's profit. The final cost will therefore be

$390,830.77 + $78,166.15 = $468,996.92 or an average cost per mile of road of $287,728.17 .

-------SPECIFICATIONS-------

for

MATERIALS and CONSTRUCTION of SEWERS,

PORTLAND CEMENT CONCRETE SIDEWALKS,

and

BRICK.

MANHOLES.

All manholes are to be circular in section and three feet internal diameter. They are to be built with two rings of brick, giving a thickness of eight inches to the wall. The bricks in the inside ring are to be set vertically. The outer ring may be built of bats as far as broken bricks on hand will go, otherwise whole bricks are to be used.

On sewers three feet in diameter and greater the manholes shall be supported by the arch invert of the sewer without additional foundation. On sewers less than three feet in diameter the invert of the sewer through the manholes shall be built of two rings of brick and on each side thereof shall be built a solid brick foundation twelve inches thick, making the entire foundation four feet and six inches in diameter.

The top of the manhole is to be two feet in diameter, being drawn in by means of six header courses, the diameter being decreased two inches for each course, and an iron cover set thereon. On unpaved streets, the tops of the covers of the manholes are to be at the surface of the streets; on paved streets, one-half inch lower.

CATCH-BASINS.

All catch-basins are to be circular in section and four feet in internal diameter. They are to be built of two rings of brick upon a floor of two-inch pine plank closely jointed. The bricks in the inner ring (excepting the top and bottom

header courses) are to be set vertically. The outer ring may may be built of bats as far as broken bricks on hand will go, otherwise whole bricks are to be used. The brick work shall be seven feet two inches deep; the top of the catch-basin shall be two feet in diameter, being drawn in by means of eight header courses, the diameter being decreased three inches for each course, a top header course, being laid flush with the course below and an iron cover set thereon.

The catch-basins are to be connected to the sewer with nine-inch pipe and trapped with nine-inch half-traps, the bottom of the traps to be set three feet and six inches above the floor of the basin.

The top of the cover shall be set at the grade required.

COVERS.

All covers used shall be of good quality of cast iron, the curb shall weigh not less than 250 pounds and the lid shall weigh not less than 120 pounds, and shall be of the same size and pattern as iron covers now in use by the Bureau of Sewers, in the City of Chicago, provided that if the catch-basins are built in the parkways, lighter covers may be used weigning not less than 140 pounds.

BRICKS.

The bricks shall be the best quality for the purpose for which they are intended, uniform in quality, sound and hard burned, free from lime and cracks, and to have a clear ringing sound when struck, whole and with edges full and square, and of standard dimensions; they shall be of compact texture,

and after being thoroughly dried and immersed in water for twenty-four hours shall not absorb more than 15 per cent in weight of water.

CEMENT.

The cement shall be fresh made, of some satisfactory and reliable brand, and of such quality and uniformity as has been demonstrated by the Board of Local Improvements of Chicago, to be of superior quality and thoroughly adapted to the construction of sewers and similar work, and shall be approved by the Engineer.

Natural cement shall be so finely ground that 80 per cent of the whole will pass through a seive of 100 meshes to the lineal inch, and when treated in the usual manner for tensile strength, shall give results comparing favorably with the best brands of American Natural Cement. The cement, when tested in the usual manner, shall take an initial set in not less than 12 minutes.

MORTAR.

The mortar for brick work shall be made by carefully measuring and thoroughly incorporating one part of natural cement with two parts of clean, sharp sand in dry state, mixed with clean water to the proper consistency, and shall be used while fresh, and the use of mortar which has set and then been retempered will not be allowed.

PORTLAND CEMENT CONCRETE SIDEWALKS.

FOUNDATION.

Soft and spongy places not affording a firm sub-foundation must be dug out and refilled with earth, cinders or other material equally as good for filling purposes, thoroughly compacted by flooding and tamping. Wherever the natural surface of the ground is not sand free from loam, the sidewalk space shall be excavated or filled, as may be necessary, and brought to a sub-grade fourteen (14") inches below final grade. Upon this sub-foundation shall be placed a layer of clean cinders, or material equally as good for foundation purposes, thoroughly flooded and rammed perfectly solid, and brought to a grade five (5") inches below and parallel with the top of the completed sidewalk. In interpreting these specifications, sand, gravel, crushed stone, or any material of a like character, free from animal or vegetable matter, will be considered "equally as good" as cinders for foundation purposes. Wherever the natural surface of the ground is sand and at grade, no other filling will be required. Wherever filling is required in preparing the sub-foundation, it shall be of earth, cinders or other material equally as good for filling purposes, free from animal or vegetable matter, and shall be deposited in layers of not more than two (2') feet in thickness, except where clay filling is used, then said layers shall not be more than one (1') foot in thickness each layer to be thoroughly compacted by flooding or tamping before the succeeding layer is put on. All filling to be done

in such manner as to leave a berm of one (1') foot on each side of and flush with the top of the completed walk, and shall slope to the surface of the ground at the rate of one and one-half (1 1/2') feet horizontal to one (1') foot vertical.

IN MAKING THE SIDEWALKS, PORTLAND CEMENT SHALL BE USED.

PORTLAND CEMENT.

The Portland cement used in this improvement shall be subject to the following inspection and tests and must be approved by the Board of Local Improvements before it is incorporated in the work;

Fineness. It shall be so ground that ninety-two (92) per cent. will pass through a standard No. 100 sieve having 10,000 meshes per square inch, made of wire cloth, No. 40 wire, Stubbs' gauge.

Soundness. It shall meet the requirements of the following boiling test; A pat of neat cement, three and one-half (3 1/2in.) inches in diameter, one-half (1/2in.) inch in thickness at the center and tapering to a thin edge, having been made on glass, and which has remained in air twenty-four (24) hours protected by a damp cloth, together with broken briquettes of neat cement, which have remained in air one (1) day and immersed in water six (6) days, shall, after being subjected to the action of steam for (4) hours and then immersed in boiling water four(4) hours, show no checking, warping or swelling.

Setting. The cement when mixed with twenty-eight (28) per cent. of water, by weight, shall take initial set in not

less than forty-five (45) minutes as determined by the Gilmore needle.

Strength. Briquettes shall develop the following ultimate tensile strengths per square inch of section; Neat—one (1) day in air and six (6) days in water, 500 pounds. One (1) part cement to three (3) parts torpedo sand or limestone screenings, one (1) day in air and six (6) days in water, 200 pounds; and shall show a gradual increase in strength of twenty (20) per cent. at the end of twenty-eight (28) days.

Samples of cement which it is proposed to use in the work shall be submitted to the Board of Local Improvements in such quantities, and at such time and place, as will enable it to make all required tests.

The Board of Local Improvements reserves the right to reject, without recourse, any cement which is not satisfactory, whether for reasons mentioned in these specifications or for any good and sufficient cause.

All cement must be delivered on the work in approved packages bearing the name, brand or stamp of the manufacturer and shall be thoroughly protected until used.

No damaged, short weight package or lumpy cement will be allowed.

SAND.

The sand to be used in making the concrete shall be known as "Torpedo," and must be clean, dry, free from dust, loam and dirt, and of sizes ranging from one-eighth(1/8") inch down to the finest, in such proportions that the voids,

as determined by saturation, shall not exceed thirty-three (33%) per cent. of the entire volume, and it shall weigh not less than one hundred (100) pounds per cubic foot. No wind-drifted sand shall be used.

The sand, when delivered on the street, shall be deposited on flooring and kept clean until used.

STONE.

The stone used in making the concrete shall be of the best quality of limestone, or stone equally as good for concrete purposes, or washed gravel, all of which shall be free from dust, loam and dirt or other foreign substances; and of sizes measuring not less than one-fourth(1/4") of an inch, or more than one (1") inch in any dimension, and when delivered on the street shall be deposited on flooring and kept clean until used.

Where washed gravel is to be used it must be delivered on the work, deposited in piles and kept separate from the torpedo sand.

The sidewalk shall be constructed at the established grade. Care must be taken to have the top lines of the walk straight and parallel, the surface of each stone being a plane, unless otherwise ordered and directed. The sidewalk shall rest on a foundation of cinders, or material equally as good (except as specified above), which must be nine (9") inches in thickness, after being thoroughly flooded and compactly rammed to an even surface.

MIXING AND LAYING OF CONCRETE.

The concrete shall be mixed on movable water-tight platforms of such size as shall accommodate the manipulations hereinafter specified.

The cement, sand and stone shall be mixed in the following proportions; One (1) part cement, two and one-half(2 1/2) parts sand and five (5) parts of stone or washed gravel. The sand and cement shall be thoroughly mixed dry, to which sufficient water shall be added, and then made into a stiff mortar. The stone or washed gravel, after having been sprinkled with water, shall then be immediately incorporated in the mortar and the mass thoroughly mixed by turning over with shovels, hoes, or mechanical mixers at least three (3) times, or until each particle of stone is thoroughly covered with mortar.

The concrete shall be removed from the platform and placed on the foundation in such quantities that after being rammed in place the layer shall be of the required thickness (four and one-fourth (4 1/4") inches), and the upper surface shall be true, and three-fourths (3/4") of an inch below and parallel with the top of the finished walk. The second,or finishing layer, three-fourths (3/4") of an inch thick, composed of two (2) parts best Portland cement, and three (3) parts clean, screened torpedo gravel, or fine granite screenings, to be put on before the first layer has set, and trowelled sufficiently to give the completed walk a smooth, even and glossy surface.

All work to be laid in blocks about five (5') feet by six (6') feet, enclosed in wood forms made of two (2")inch by five (5") inch scantling, and blocks must be laid alternately, leaving the intervening space until all alternate blocks are laid and cement set.

During the progress of the work the sub-grade must be kept moist.

SLOPE. All sidewalks to be so constructed that completed the top surface shall coincide with the grade of the space between the curb line and the street line, which grade shall be in a uniform incline from the street line toward the curb line, with a fall of one (1") inch in every three (3') feet.

BRICK.

COMBINED CURB AND GUTTER.

In making the combined curb and gutter Portland cement shall be used and ordinarily will be subjected to the following inspection and tests;

Fineness. It shall be so ground that ninety-two (92) per cent. will pass through a standard No. 100 sieve having 10,000 meshes per square inch.

Soundness. It shall meet the requirement of the "Boiling" test.

Setting. The cement when mixed with twenty (20) per cent. of water, by measure, shall take initial set in not less than forty-five (45) minutes.

Strength. Briquettes, one (1") inch square in section, shall develop the following ultimate tensile strength; Neat--one day in air and 6 days in water, 400 pounds. One (1) part cement to two (2) parts fine granite screenings---one day in air and six days in water, 200 pounds; and shall show a gradual increase in strength of fifteen (15) per cent. at the end of twenty-eight (28) days.

Samples of cements which it is proposed to use in the work, shall be submitted to the Board of Local Improvements in such quantities and such time and place as to make all the required tests.

The Board of Local Improvements reserves the right to reject, without recourse, any cement which is not satisfactory, whether for reasons mentioned in these specifications or

for any good and sufficient cause.

All cement to be used in the combined curb and gutter must be delivered on the work in approved packages bearing the name, brand or stamp of the manufacturer. It shall be thoroughly protected from the weatner until used, in such manner as may be directed.

The granite screenings used in making the concrete shall be clean, dry, free from dust, loam and dirt, and when delivered on the street shall be deposited on flooring, and kept clean until used.

The crushed granite shall be clean, free from dust and dirt, broken so as to measure not more than one (1") inch in any dimension, and when delivered on the street shall be deposited on a flooring and kept clean until used.

The granite concrete combined curb and gutter shall be constructed at the established grade and in a continous line on each side of the street, twenty (20') feet from and parallelwith the center line thereof. The combined curb and gutter shall rest on a foundation of cinders which must be six (6")inches in thickness after being thoroughly flooded and compactly rammed to an even surface.

The curb and gutter shall be made of concrete formed by intimately mixing one (1) part of cement with two (2) parts of fine granite screenings; to this mixture shall be added four (4) parts of crushed granite and the whole thoroughly mixed together after which just sufficient water to wet the mass shall be added, so that when it is rammed in place a film of moisture shall appear on top. All exposed surfaces

shall be covered with a finishing coat of mortar three-eighths (3/8") inches in thickness, composed of one (1) part of the cement thoroughly mixed with one and one-half (1 1/2) parts of the fine granite screenings. Before the concrete sets, the curb and gutter shall be cut into sections not exceeding six (6') feet in length.

The gutter flag must be eighteen (18") wide and five (5") inches thick; the curb must be seven (7") inches thick throughout, except at the upper face corner, which is to be rounded to a radius of one and one-half (1 1/2") inches. The height of the curb above the gutter flags will be twelve (12") inches.

PREPARATION OF SUB-GRADE.

Where filling is required it shall be of earth or cinders, free from animal or vegetable matter, and shall be deposited in layers of not more than two (2') feet in thickness, and shall be thoroughly compacted.

All necessary filling to bring the street to sub-grade and to properly back-fill the curb, shall be deposited on the street before any curb is set.

In all cases where curb is set the back-filling shall have a berme of at least four (4') feet behind the curb, at the top thereof, with a slope of one and one-half (1 1/2) horizontal to one (1) vertical.

Where cutting is required the earth must be excavated to such depth as may be necessary to bring the roadway to the proper sub-grade after having been thoroughly compacted.

The road-way shall be brought to sub-grade by cutting or

filling as may be necessary; said subgrade shall be eleven and one-half (11 1/2") inches below and parallel with the top of the finished pavement after having been thoroughly compacted and secured from further settlement by flooding, ramming or rolling, or all,as may be deemed necessary by the Engineer.

CONCRETE FOUNDATION.

On the sub-grade as above prepared shall be laid a foundation of Portland cement concrete to a uniform thickness of six (6") inches.

CEMENT.

In making the concrete, Portland cement shall be used and ordinarily will be subjected to the following inspection and tests;

Fineness. It shall be so ground that ninety-two (92) per cent will pass through a standard No. 100 sieve having 10,000 meshes per square inch.

Soundness. It shall meet the requirements of the "Boiling" test.

Setting. The cement when mixed with twenty (20) per ce t. of water, by measure, shall take initial set in not less than forty-five (45) minutes.

Strength. Briquettes, one (1") inch square in section, shall develop the following ultimate tensile strength; Neat-- one day in air and six (6) days in water, 400 pounds. One (1) part cement to three (3) parts sand as hereinafter specified, one (1) day in air and six (6) days in water, 175 pounds; and shall show a gradual increase in strength of fifteen (15) per cent. at the end of twenty-eight (28) days.

Samples of the cement which it is proposed to use in the work, shall be submitted to the Board of Local Improvements in such quantities, and at such time and place, as will enable it to make all required tests.

The Board of Local Improvements reserves the right to reject, without recourse, any cement which is not satisfactory, whether for reasons mentioned in these specifications or for any good and sufficient cause.

All cement to be used in the concrete foundation must be delivered on the work in approved packages bearing the name, brand or stamp of the manufacturer. It shall be thoroughly protected from the weather until used, in such manner as may be directed.

SAND.

The sand used in making the concrete shall be clean, dry, free from dust, loam and dirt, of sizes ranging from one-eighth (1/8") down to the finest, and in such proportion that the voids as determined by saturation shall not exceed thirty-three (33) per cent. of the entire volume, and it shall weigh not less than one hundred (100) pounds per cubic foot.

No wind-drifted sand shall be used.

The sand when delivered on the street shall be deposited on flooring and kept clean until used.

CRUSHED STONE.

The crushed stone used in making the concrete shall be of the best quality of limestone, clean, free from dirt, broken so as to measure not more than two (2") inches and not

less than one (1") inch in any dimension.

The stone when delivered on the street shall be deposited on flooring and kept clean until used.

MIXING AND LAYING OF CONCRETE.

The concrete shall be mixed on movable tight iron platforms of such size as shall accommodate the manipulations hereinafter specified.

The cement, sand and stone shall be mixed in the following proportions; One (1) part of cement, three (3) parts of sand and seven(7) parts of crushed stone. The sand and cement shall be thoroughly mixed, dry, to which sufficient water shall be added and then made into a stiff mortar. The crushed stone shall then be immediately incorporated in the mortar and the mass thoroughly mixed, adding water from time to time as the mixing progresses, until each particle of stone is covered with mortar.

The concrete shall be removed from the platform with shovels and deposited in a layer on the roadway in such quantities that after being rammed in place it shall be of the required thickness and the upper shall be smooth and five and one-half (5 1/2") inches below and parallel with the top of the finished pavement.

During the progress of the work the sub-grade must be kept moist.

The concrete shall be sprinkled so as to prevent cracking in hot weather, and shall be protected from injury at all times, and shall lay at least seven days before being covered with the wearing surface, or a longer time if deemed necess-

ary.

SAND CUSHION.

Upon the concrete foundation shall be spread a layer of sand in such quantity as to insure, when compacted, a uniform thickness of one (1") inch.

On surfacing said layer of sand the contractor or contractors shall use such guides and templets as the Engineer may direct.

WEARING SURFACE.

Upon the layer of sand as above specified shall be placed the brick of such quality and in such manner as hereinafter specified.

QUALITY OF BRICK.

The brick to be used shall be of the best quality of vitrified paving brick. Salt glazed bricks will not be received.

The dimensions of the brick used shall be the same throughout the entire work in any particular case, and shall be not less than eight (8") inches in length, four (4") inches in depth, and two and one-half (2 1/2") inches in thickness, with rounded edges to a radius of one-quarter (1/4") of an inch.

Said brick shall be of a kind known as repressed vitrified paving brick and shall be repressed to the extent that the maximum amount of material is forced into them. They shall be free from lime and other impurities, shall be as nearly uniform in every respect as possible, shall be burned so as to secure the maximum hardness, so annealed as to reach

the ultimate degree of roughness and thoroughly vitrified so as to make a homogeneous mass.

The bricks shall be free from all laminations caused by the process of manufacture, and free from fire cracks or checks of more than superficial character or extent.

A specimen brick, shall be submitted to a"water absorbtion" test, and if such brick show a water absorption exceeding three (3) per cent. of their weight when dry, the same shall be rejected. Such "water absorption" test shall be made by the Board of Local Improvements of the City of Chicago, in the following manner, to wit; Not less than three (3) bricks shall be broken across, thoroughly dried, and then immersed in water for seventy-two (72) hours. The absorption shall then be determined by the difference between the weight dry and the weight at the expiration of said seventy-two (72) hours.

Twenty or more specimen bricks shall be furnished for submission to the "abrasion" test by the Board of Local Improvements. Such test shall be made in the following manner, to wit; Such specimen brick or a sufficient number to fill 15 per cent of the volume of the rattler shall be submitted to a test for one hour in the machine known as the "Rattler," which shall measure twenty (20") inches in length and twenty-eight (28") inches in diameter, inside measurement, and shall be revolved at the rate of thirty (30) revolutions per minute. If the loss of weight by abrasion during such test shall exceed twenty (20) per cent of the original weight of the brick tested, then such brick shall be rejected.

All brick shall have a specific gravity of not less than two and one-tenth (2 1/10), as determined by the formula--- specific gravity equals $\frac{W}{W'-W''}$; where W equals weight of brick dry, W' equals weight of brick after being immersed in water for seventy-two (72) hours, and w" equals weight of brick in water.

HOW LAID.

All bricks shall be delivered on the work in barrows, and in no case will teams be allowed on the street before the wearing surface is rolled.

Broken bricks can only be used to break joints in starting courses and in making closures, but in no case shall less than half a brick be used.

The bricks shall be laid on edge, close together, in straight lines across the roadway, between gutters, and at right angles to the curbs and perpendicular to the grade of the street.

The joints shall be broken by a lap of not less than three (3") inches.

The bricks when set shall be rolled with a roller weighing not less than five (5) tons until the bricks are well settled and made firm. Or, the bricks, when set, shall be thoroughly rammed two or more times. The ramming to be done under a flatter, with a paving rammer weighing not less than thirty (30) pounds, the iron of the rammer face in no case to come in contact with the pavement.

After rolling and ramming, all broken brick found in the pavement must be removed at once and replaced by sound and

perfect brick.

PITCHING OR GROUTING AND TOP DRESSING.

When the brick are thoroughly bedded, the surface of the pavement must be true for grade and crown. The surface of the pavement shall be swept clean, and the joints or spaces between the brick shall be completely filled with a paving pitch is the direct result of the distillation of "straight run" coal tar, and of such quality and consistency as shall be approved by the Board of Local Improvements. The pitch must be used at a temperature of not less than 280 degrees Fahrenheit.

When the brick are thoroughly bedded, the surface of the pavement must be true for grade and, crown. The surface of the pavement shall then be swept clean, and the joints or spaces between the bricks shall be filled with a cement grout filler composed of limestone 65 per cent., furnace slag 25 per cent. and potters' clay 10 per cent., to be made as follows; The above material in the proportions stated shall be mixed together and ground into an impalpable powder, and then burned in kilns until reduced to clinker after which it shall again be ground into an impalpable powder. Equal portions of said grout and clean sharp sand shall then be thoroughly mixed, and sufficient water added to bring the mixture to such a consistency as will allow it to run to the bottom of the joints between the brick. After said joints are filled to the top, the surface shall be finished off smoothly with steel brooms.

After the spaces between the brick have been filled with

the pitch or grout as above specified, the surface of the pavement shall then receive a one-half (1/2") inch dressing of sand, evenly spread over the whole surface.

Where cement grout is used as a filler the pavement must be kept clear of traffic for a period of four (4) days after the application thereof.

72nd Street Looking West

Showing Present Bridge

Construction

View Looking North Showing
Through Girders at
76th Street

Present Grade Crossing
View from 19th Street
C. R. I. & P. R. R Tracks on Left
C. & W. I. R. R. Tracks on Right.

BIBLIOGRAPHY.

TRACK.ELEVATION.

Books.

625.1 Beahan,
B35 Field treatice of railway location.

625 Camp,
C15 Notes on track.

620.02 Gillette,
G41 Cost data.

625.1 Tratman,
T69 Railway track & track work.

625 Wellington,
W46 Railroad location.

Periodicals.

Track elevation - Chicago & Northwestern Ry.
Engineering News, 36-114.

Elevation of the N.Y., N.H. & Hartford R.R. at Boston, Mass.
Engineering News, 37-18

Track Elevation at Brockton, Mass.
Engineering News, 37-178

Progress of track elevation by the C. & N.W. Ry. in Chicago,
Engineering News, 38-286

Track elevation at Chicago,
Engineering News, 39-73

Track elevation & depression at the 16th St. Crossing Chicago,
Engineering News, 40-22

Track elevation in Chicago,
Engineering News, 40-97

Track elevation of the Erie R.R. through Jersey City, N.J.,
Engineering News 40-111

Track elevation & depression at 16th St. & Clark St.,
Engineering News, 41-235

Track elevation in Chicago,
Engineering News, 43-18,24,122,149,385

Extent of work done in Chicago,
Engineering News, 45-89, 140

Report on track elevation at Cincinnati,Ohio,
Engineering News, 46-171

Track elevation &depression at Milwaukee,
Engineering News, 53-264

Track elevation on the C. & N. W. Ry.,
Engineering News, 54-244

Track elevation on the Pennsylvania line at Chicago,
Engineering News, 56-6 July 5, 1906.

Park Ave. viaduct improvement N.Y.,
Engineering Record, 34-309

Erection of the Park Ave. viaduct N. Y.,
Engineering Record, 35-269

Track elevation at Chicago on the P., F.W. & C. Ry.,
Engineering Record, 53-759

Track elevation in Chicago,
Journal of the West. Soc. of Engineers, 3-1227, 1341

Kinzie street track elevation in Chicago,
R. R. Gazette, 39-442

Track elevation in Chicago,
Railway Age, 23-440

Track elevation of the C. & W.I. Ry.,
Railway Age, 39-387

Chicago & Western Indiana Ry. track elevation at Chicago,
Railway Age, 41-433

Vandalia track elevation at Indianapolis,
Railway Age, 41-435

Pittsburg, Ft, Wayne & Chicago Ry. track elevation,
Railway Age, 41-1230

John Crerar Library.

620.2 Patton,
P500 Treatise on Civil Engineering. Index under track.

Work of the N.Y. Central R.R. in N.Y. City,
R. R. Gazette, April 12, 1895.

Railroad track elevation in Chicago,
R. R. Gazette, July 26, 1895.

Track elevation on the Milwaukee division of the C. & N. W.Ry.
R. R. Gazette, Aug. 7, 1896.

Track elevation at South Norwalk,
R. R. Gazette, Sept. 4, 1896.

Track elevation in Chicago,
R. R. Gazette, Nov. 6, 1896.

N. Y. Central track elevation,
R. R. Gazette, Jan. 8, 1897.

Erie track elevation in Jersey City,
R. R. Gazette, Jan. 29, 1897.

Chicago track elevation,
R. R. Gazette, Aug. 13, 1897.

Track elevation in Chicago,
R. R. Gazette, Jan. 14, 1898.
Feb. 4, 1898.

1.

THESIS

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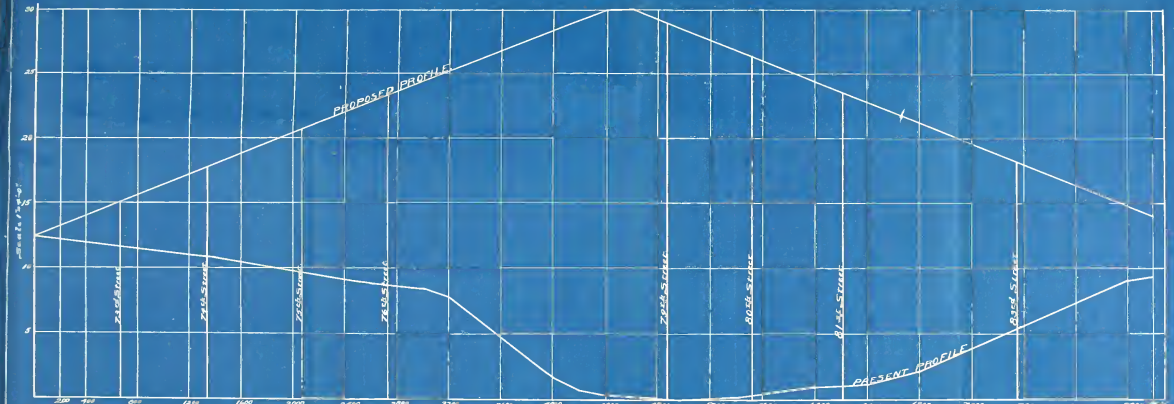
ARMOUR INSTITUTE of TECHNOLOGY
1907

John Whitbridge E B Badger

79th S. creek

3800

PLATE 1.



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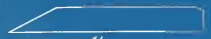
SED CROSS-SECTIONS

to 83rd Street

100'-00"

7

Badgers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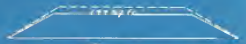
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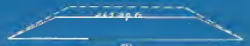
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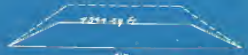
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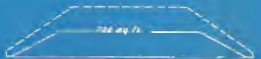
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PLATE 2


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#41


#42


#43


#44


#48


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#51


#52


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THESIS

Civil Engineering Department

ARMOUR INSTITUTE of TECHNOLOGY

Present's Proposed Cross-Sections

From

72nd Street to 95th Street

at

Intervals of 100' 00"

1907

Scale 1/8" = 1'-0"

F. Blake '07

A. Sedgwick '07

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1907.

H. B. Badger

John F. Hallowell

PLATE 3.

General Plan 70 W. St. to 73rd St.
Scale 1/16"

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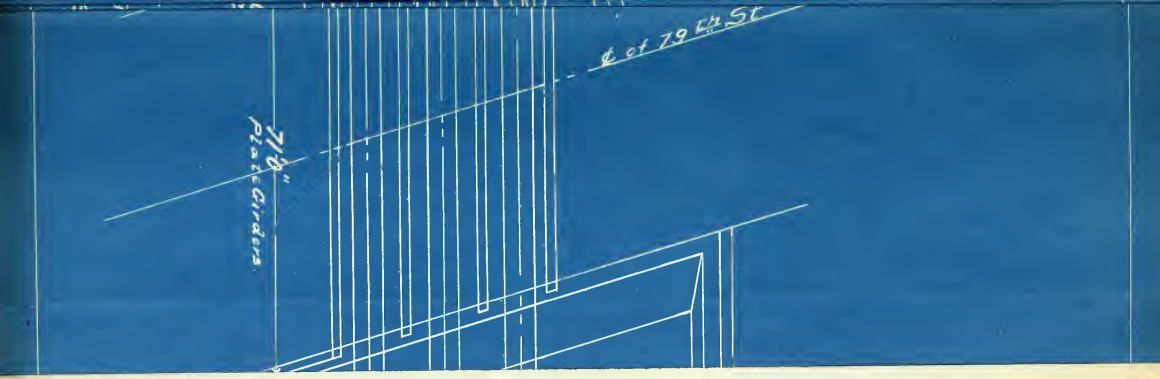
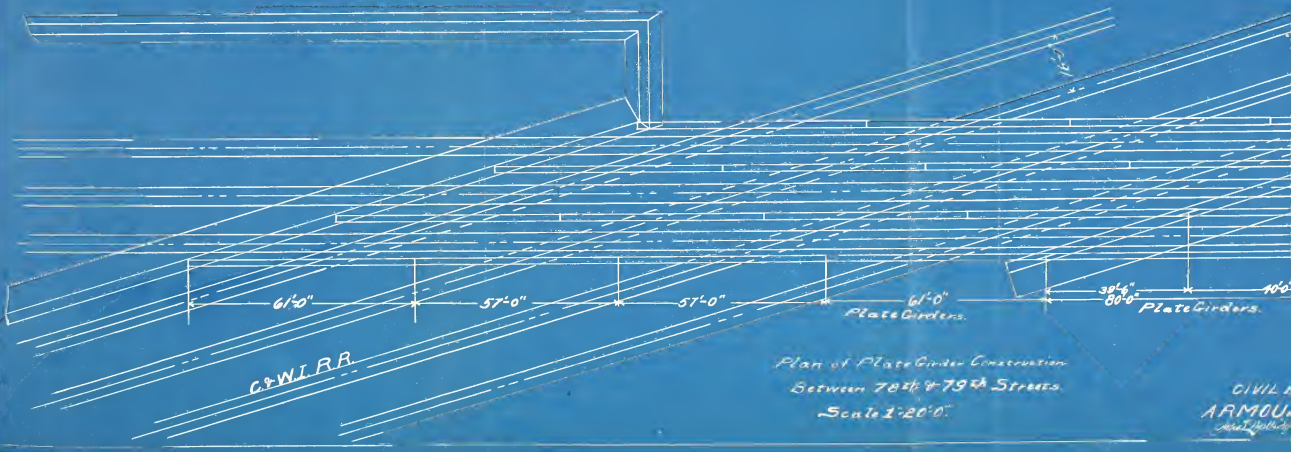

℄ of 79th St
71'0"
Plate Girders

PLATE 4.



Plan of Plate Girder Construction
Between 78th & 79th Streets.
Scale 1:20'-0".

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ARMOU

E 4.

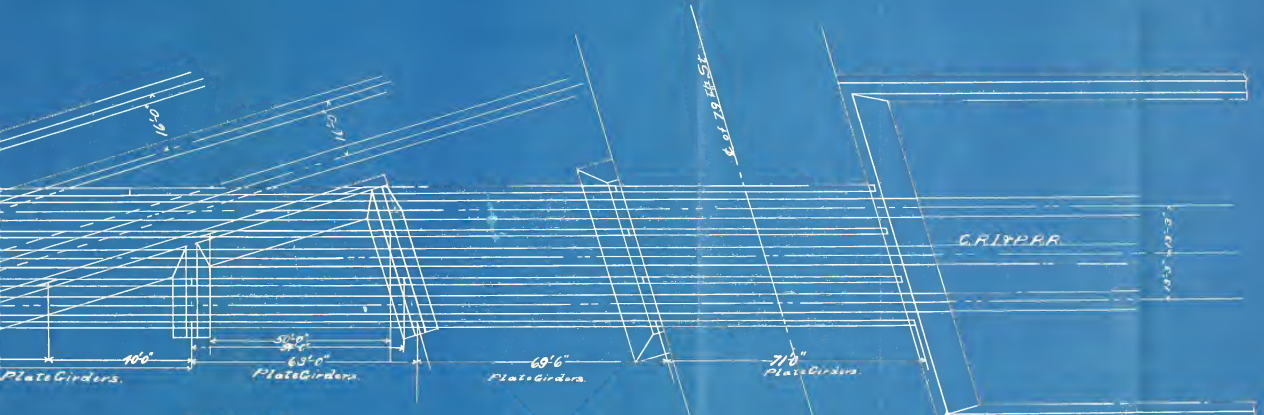

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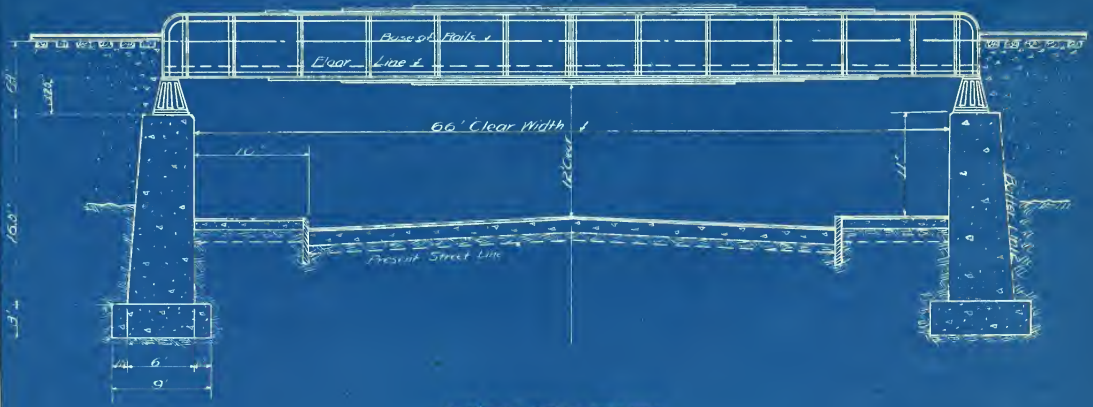
PLATE 5.



73rd STREET CROSSING
Section near Bridge
Scale 1in=10Ft.

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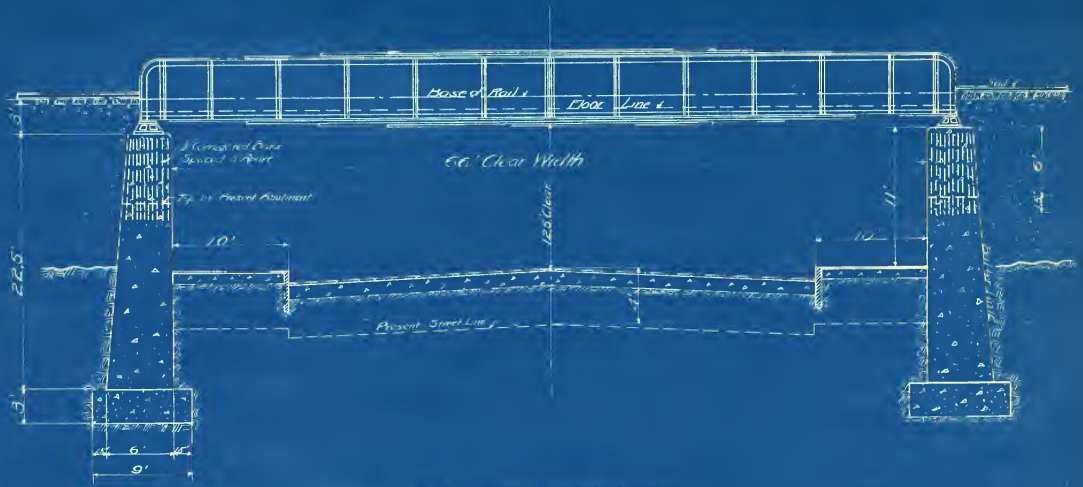
PLATE 6.



74th STREET CROSSING
Section near Bridge
Scale 1in=10 Ft.

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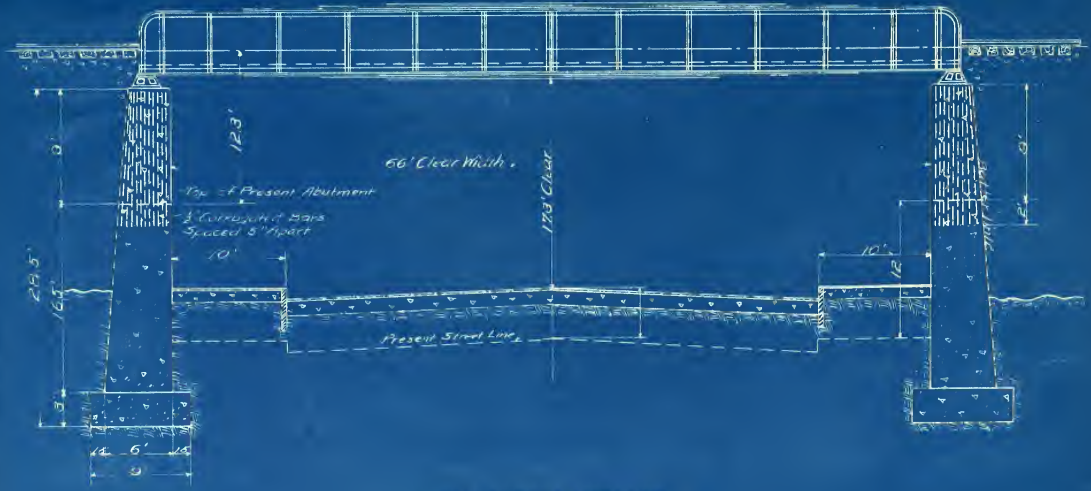
Chicago 1907

PLATE 7.



75th STREET CROSSING

Section near Bridge

Scale in inch

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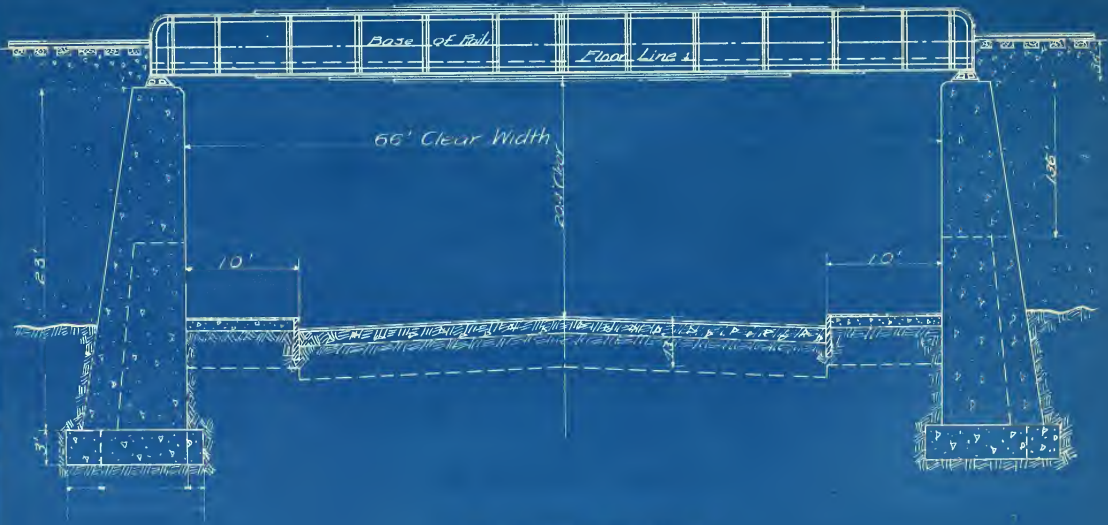
A. Badger 1907 Jos. Ridge

PLATE 8.



76th STREET CROSSING
Section near Bridge
Scale 1in = 10ft

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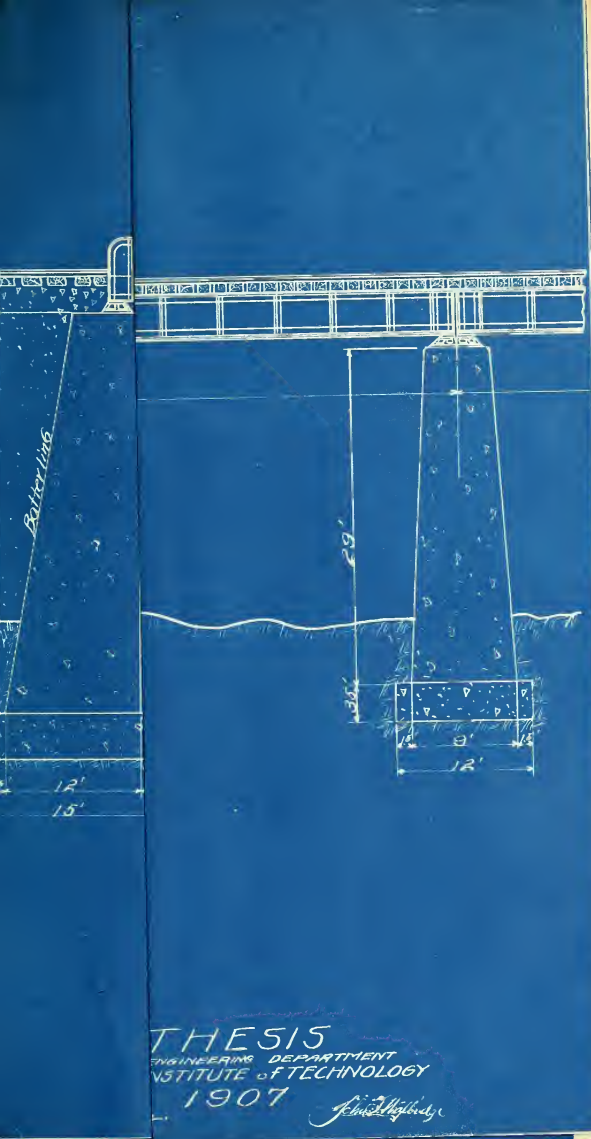

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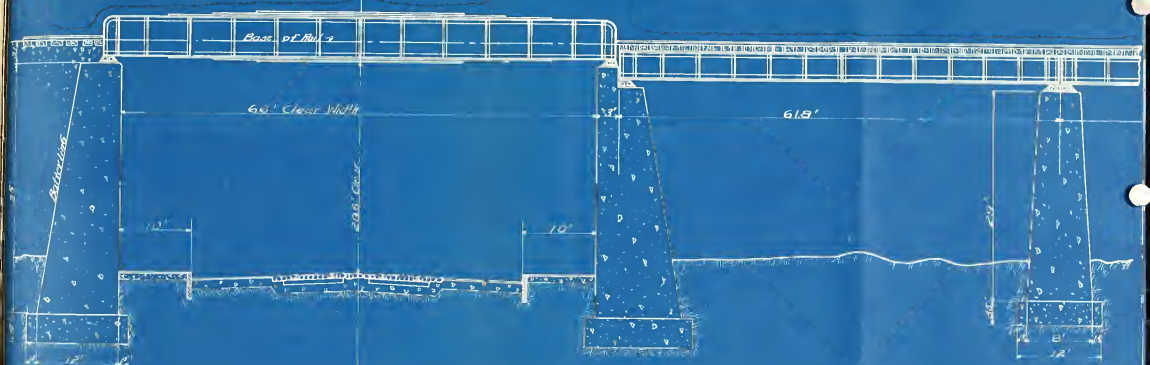
PLATE 9.



79th CROSSING AND FIRST LEVEL GIRDER TO THE NORTH
SECTION PERPENDICULAR TO 79th STREET
Scale 1in=1ft.

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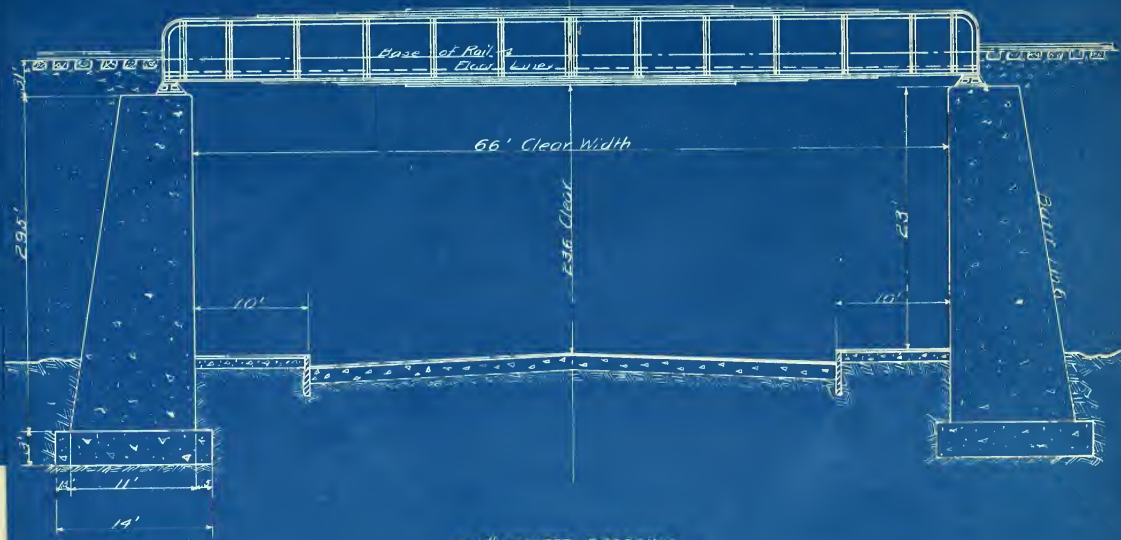
PLATE 10.



80th STREET CROSSING
Section near Bridge
Scale 1in 10ft.

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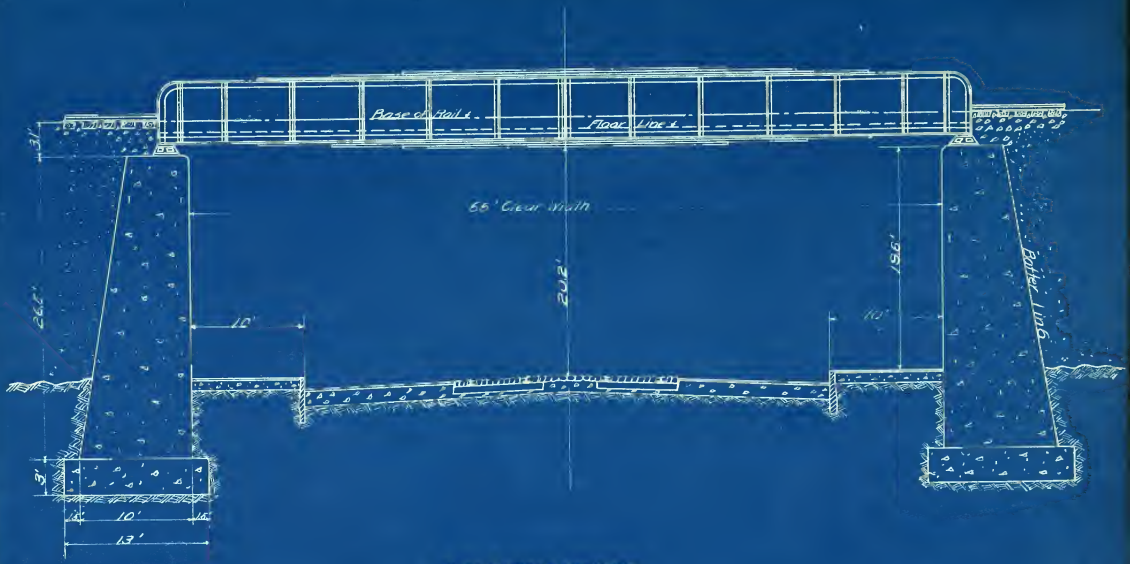
PLATE 11.



81st STREET CROSSING
Section near Bridge
Scale 1in=10ft.

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PLATE 12.

83d STREET CROSSING
Section near Bridge
Scale 1"=10ft.

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John F. Hattenbergh

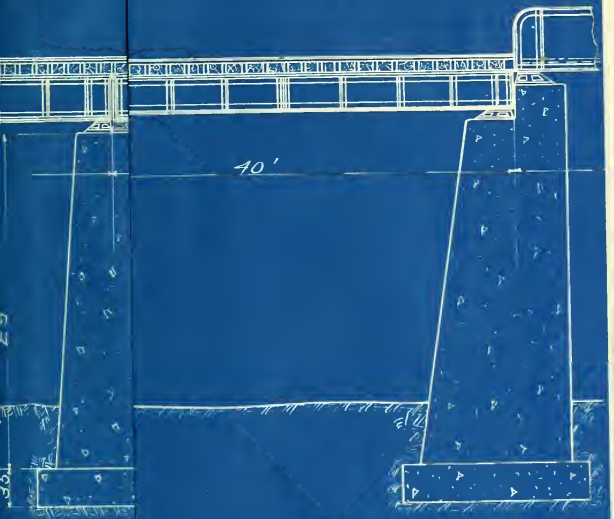

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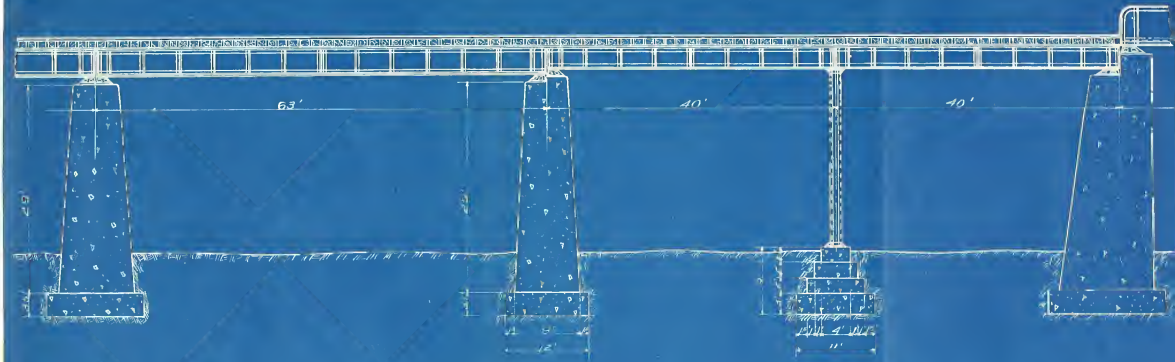
PLATE 13.



SECTION SHOWING 2nd, 3rd & 4th BLOCK GIRDER SPANS NORTH OF 79th STREET
Section Parellel to C.R.I.&P.Ry TRACKS
Scale 1in=10ft.

PLATE 14.

THESIS.

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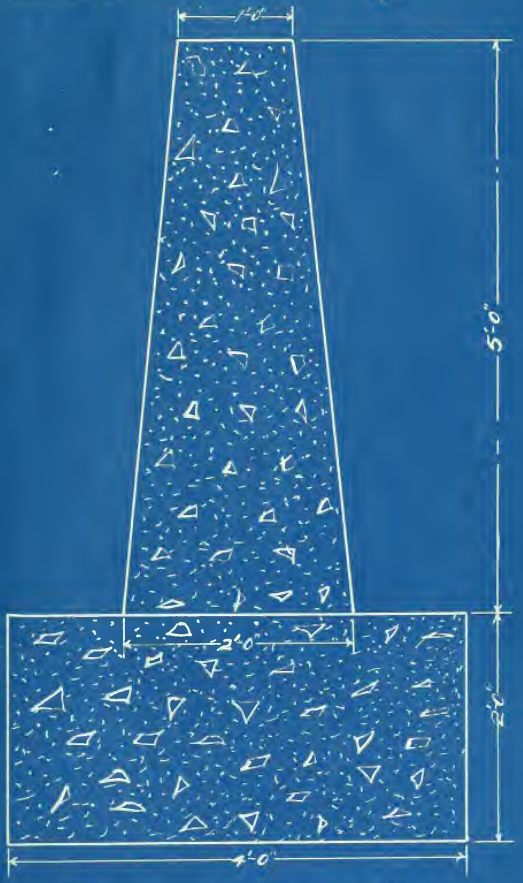
John W. Mullaly 1907 A. Badger.



SECTION of RETAINING WALL
from
75th to 76th & 81st to 83rd Streets.
Scale 1"=1'-0".

PLATE 13.

THESIS.

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ARMOUR INSTITUTE of TECHNOLOGY.

Thos. E. Hutchings 1907 G. F. Badger.

SECTION of RETAINING WALL
from.
80th to 81st Streets.
Scale ½"=1'-0"

PLATE 16.

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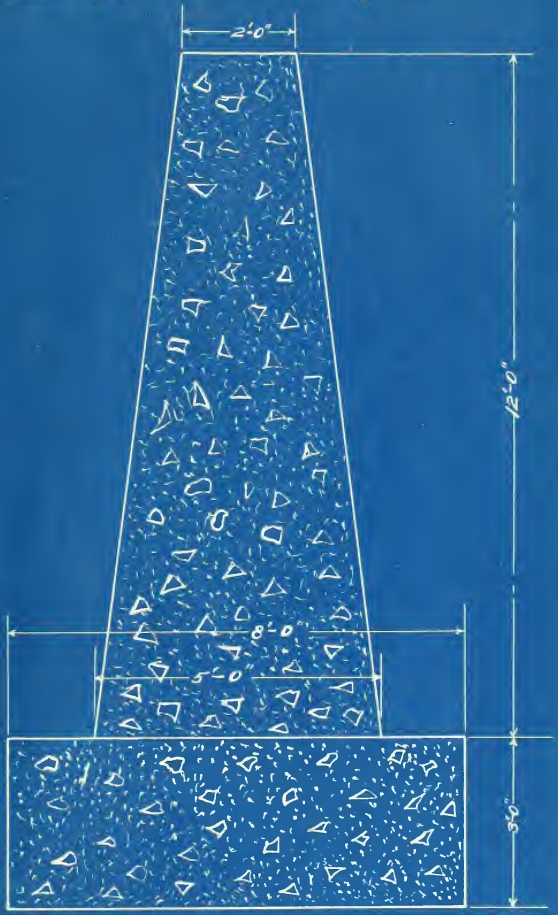
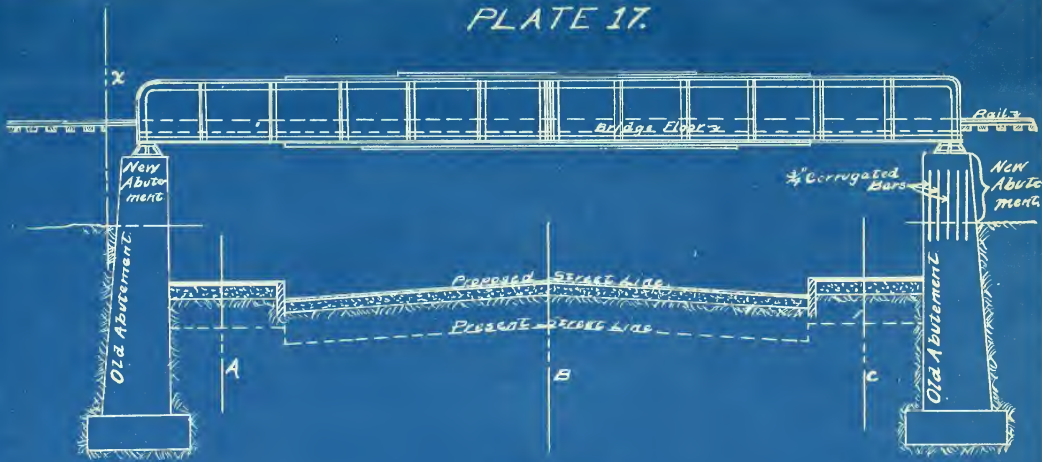
Thos. McClintock, 1907. E. Badger.



SECTION of RETAINING WALL
from
76th to 79th & 79th to 80th Streets.
Scale ½"=1'-0"

PLATE 17.



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1907.

Scale 1"=10'-0"

John F. Millundy

H. Badger.

ES 15.
IG DEPARTMENT
ITE OF TECHNOLOGY
07. H. Badger

ON CENTER LINE OF BRIDGE

terial.

t ties)

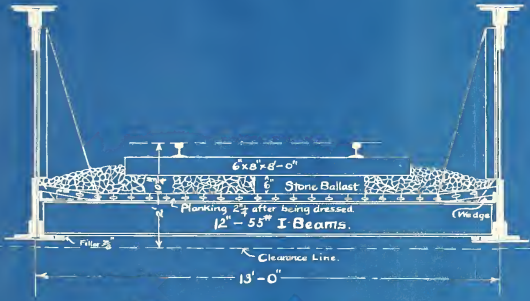
to 12'-5½" spaced from 13" to 16" c. to c.

PLATE 18.

I-BEAM FLOOR.

Scale $\frac{1}{2}$"=1'.

THESIS
CIVIL ENGINEERING DEPARTMENT
ARMOUR INSTITUTE of TECHNOLOGY
Approved by 1907 A.J. Bodger



CROSS SECTION AT END OF BRIDGE

LONGITUDINAL SECTION ON CENTER LINE OF BRIDGE

Material

All Timber to be Treated (forked ties)
I Beams varying from 12"-40# to 12"-55# Spaced from 13'6" to 16' c.to.c.